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Title: Nuclear Data Needs for Radiochemistry

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## Memorandum

DICER-LDRD-DR

**To:** DICER Collaboration

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**Date:** March 29, 2021

### **Subject: Nuclear Data Needs for Radiochemistry**

There are many elements of interest to the weapons community that include light elements, activation products, fission products, actinides and heavy elements. Of course, that is the whole periodic table! In this memo we summarize a down-selected list, 22 of 118+ of elements that have or could serve as radiochemical diagnostic measurements. The simulations would need cross sections for nuclides (and metastable states) of these elements to be able to calculate values for comparison with debris measurements. The purpose of this memo is to:

1. Allow the experimental community to provide input on what is possible and not possible, due to half-lives, for example, as well as current experimental and target production constraints.
2. Allow the nuclear theory community to provide input on what measurements they would need to constrain their models to predict cross sections for the nuclides of interest.

The goal is to be able to go after low hanging fruit and help set expectations and needs for future challenging measurements and associated costs to accomplish them. A classified memo will also be generated.

In the sections below we provide an alphabetized list of elements along with their nuclides that are of interest. Also included are what cross sections libraries are currently available at LANL through the XCP-5 nuclear data team for each nuclide. Note that a new library does not mean that a new evaluation has been performed for a given isotope. We have included information on the evaluation used for each isotope and library to the extent possible. Note that Ed Arthur from the LANL group T-2 provided a number of evaluations from 1978-1984. We have used "LANL 1980" as a designator for these evaluations as it is difficult to establish the specific year for each. It is also worthwhile to mention that for the historical libraries CRSDATA, Y21GRP\_N and Y21GRP the binary data library format at the time only allowed for a limited number of reactions. Hence, different choices were made between LLNL and LANL about how to include the sum of multiple reactions for an isotope into one of those limited slots (Seamon 1989). Unfortunately, when modern libraries have been created and used historic data these same limitations may exist in the data set as it was a translation from the binary format to the modern format and not a complete reprocessing of the historical evaluations.

We ask the theory and experimental communities to fill out their "needs" or "requirements" to calculate or measure each of the listed nuclides. Then an updated version of this memo can provide a foundation upon to request funding to support theoretical calculations and experimental measurements to fill in holes and provide better data. We will also continue adding more production/depletion chain figures and references to documentation for each nuclide.

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## Ag – Silver (Z = 47)

Table V  
Production/Depletion for Silver Isotopes

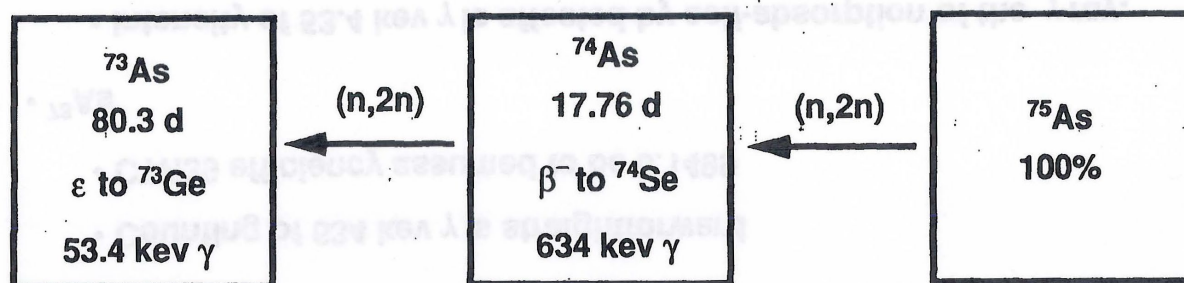
Reaction	Target	Product	Target	Reaction	Product	MT	Reactions	ZAID on Dosimetry Files
	1		104gAg					0.00
	2		105gAg					0.00
1	3	2	106mAg	(n,2n)	105gAg	16	See Note	47106.313
2	3	1		(n,3n)	104gAg	17		
3	2	5		(n,g)	107gAg	102		
4	4	2	106gAg	(n,2n)	105gAg	16	See Note	47106.303
5	4	1		(n,3n)	104gAg	17		
6	4	5		(n,g)	107gAg	102		
7	5	4	107gAg	(n,2n)	106gAg	16	See Note	47107.303
8	5	3		(n,2n)	106mAg	1016		
9	5	2		(n,3n)	105gAg	17		
10	5	FPP		(n,ds)	FPP	103, 107		
11	5	6		(n,g)	108mAg	102		
12	5	7		(n,g)	108gAg	1102		
13	6	5	108mAg	(n,2n)	107gAg	16		47108.313
14	6	4		(n,3n)	106gAg	17		
15	6	8		(n,g)	109gAg	102		
16	7	5	108gAg	(n,2n)	107gAg	16		47108.303
17	7	4		(n,3n)	106gAg	17		
18	7	8		(n,g)	109gAg	102		
19	8	7	109gAg	(n,2n)	108gAg	16		47109.303
20	8	6		(n,2n)	108mAg	1016		
21	8	5		(n,3n)	107gAg	17		
22	8	FPP		(n,ds)	FPP	103, 107		
23	8	9		(n,g)	110mAg	102		
24	8	10		(n,g)	110gAg	1102		
25	9	8	110mAg	(n,2n)	109gAg	16		47110.313
26	9	7		(n,3n)	108gAg	17		
27	9	11		(n,g)	111gAg	102		
28	10	8	110gAg	(n,2n)	109gAg	16		47110.303
29	10	7		(n,3n)	108gAg	17		
30	10	11		(n,g)	111gAg	102		
	11		111gAg					0.00

Note: Threshold for this reaction is above 17.0 MeV

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	104 (1.15 h)	-			
	105 (41.3 d)	-			
	106 (8.28 d)	crsdata	ACTL - 1978		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	106m (24 m)	crsdata	ACTL - 1978		
107 (51.84%)		crsdata	ACTL - 1978		
	108 (438 y)	crsdata	ACTL - 1978		
	108m (2.39 m)	crsdata	ACTL - 1978		
109 (48.16%)		crsdata	ACTL - 1978		
	110 (249.8 d)	crsdata	ACTL - 1978		
	110m (24.6 s)	crsdata	ACTL - 1978		
	111 (7.47 d)	-			

As – Arsenic ( $Z = 33$ )

Arsenic chain by (Mroz 1992), just showing the (n,2n) reactions from the stable.



Arsenic chain from (Lee 2013) that includes the (n,3n) and the green lines include both the (n,2n) and (n,g) reactions.

The As data main sources are (Herring 2008) for the mendf80 and (White 2004) for the CRSData.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	72 (26 h)	-			
	73 (80.3 d)	mendf80	Created from ENDF/B-VII.0 for As-75 and As-73 from LANL 1980		
	74 (17.78 d)	mendf80 crsdata	ENDF/B-VII.0 LANL 1980		
75 (100%)		mendf80 crsdata	ENDF/B-VII.0 LANL 1980		

Au – Gold ( $Z = 79$ )

Table IX  
Production/Depletion for Gold Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT Reactions	ZAID on Dosimetry Files
	1		192gAu				0.00
1	2	3	193gAu	(n, g)	194gAu	102	79193.303
2	3	2	194gAu	(n, 2n)	193gAu	16	79194.303
3	3	1		(n, 3n)	192gAu	17	
4	3	4		(n, g)	195gAu	102	
5	4	3	195gAu	(n, 2n)	194gAu	16	79195.303
6	4	2		(n, 3n)	193gAu	17	
7	4	6		(n, g)	196gAu	102	
8	5	4	196mAu	(n, 2n)	195gAu	16	79196.313
9	5	3		(n, 3n)	194gAu	17	
10	5	7		(n, g)	197gAu	102	
11	6	4	196gAu	(n, 2n)	195gAu	16	79196.303
12	6	3		(n, 3n)	194gAu	17	
13	6	7		(n, g)	197gAu	102	
14	7	6	197gAu	(n, 2n)	196gAu	16	79197.303
15	7	5		(n, 2n)	196mAu	1016	
16	7	4		(n, 3n)	195gAu	17	
17	7	FPP		(n, ds)	FPP	103, 107	
18	7	8		(n, g)	198gAu	102	
19	8	7	198gAu	(n, 2n)	197gAu	16	79198.303
20	8	6		(n, 3n)	196gAu	17	
21	8	9		(n, g)	199gAu	102	
22	9	8	199gAu	(n, 2n)	198gAu	16	79199.303
23	9	7		(n, 3n)	197gAu	17	
24	9	10		(n, g)	200gAu	102	
25	10	9	200gAu	(n, 2n)	199gAu	16	79200.303

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	193 (17.6 h)	crsdata	ACTL - 1978		
	194 (1.58 d)	crsdata	ACTL - 1978		
	195 (166.12 d)	crsdata	ACTL - 1978		
	196 (6.167 d)	crsdata	ACTL - 1978		



Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	196m (9.6 h)	crsdata	ACTL - 1978		
197 (100%)		crsdata	ACTL - 1978		
	198 (2.6949 d)	crsdata	ACTL - 1978		
	199 (3.14 d)	crsdata	ACTL - 1978		
	200 (18.7 h)	crsdata	ACTL - 1978		

Bi – Bismuth (Z = 83)

Production/Depletion for Bismuth Isotopes							ZAID on Dosimetry Files
Reaction	Target	Product	Target	Reaction	Product	MT Reactions	
	1		206gBi				0.00
	2		207gBi				0.00
1	3	2	208gBi	(n,2n)	207gBi	16	83208.303
2	3	1		(n,3n)	206gBi	17	
3	3	FPP		(n,ds)	FPP	28, 22, 103, 107	
4	3	4		(n,g)	209gBi	102	
5	4	3	209gBi	(n,2n)	208gBi	16	83209.303
6	4	2		(n,3n)	207gBi	17	
7	4	FPP		(n,ds)	FPP	22, 103, 107	
8	4	6		(n,g)	210gBi	102	
9	4	5		(n,g)	210mBi	1102	83210.313
10	5	4	210mBi	(n,2n)	209gBi	16	
11	5	3		(n,3n)	208gBi	17	
12	5	FPP		(n,ds)	FPP	28, 22, 103, 107	
13	5	7		(n,g)	211gBi	102	83210.303
14	6	4	210gBi	(n,2n)	209gBi	16	
15	6	3		(n,3n)	208gBi	17	
16	6	FPP		(n,ds)	FPP	28, 22, 103, 107	
17	6	7		(n,g)	211gBi	102	0.00
	7		211gBi				

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	204 (11.2 h)	-			
	205 (15.31 d)	-			
	206 (6.243 d)	-			
	207 (32 y)	-			
	208 (3.58 10 <sup>5</sup> y)	crsdata	ACTL - 1978		
209 (100%)		crsdata	ACTL - 1978		
	210 (3 10 <sup>5</sup> y)	crsdata	ACTL - 1978		
	210m (5.01 d)	crsdata	ACTL - 1978		

## Ca – Calcium (Z = 20)

Production/Depletion for Calcium Isotopes							ZAID on Dosimetry Files
Reaction	Target	Product	Target	Reaction	Product	MT Reactions	
	1		38gCa				0.00
1	2	1	39gCa	(n,2n)	38gCa	16	20039.303
2	2	FPP		(n,ds)	FPP	28,22,103,107	
3	2	3		(n,g)	40gCa	102	
4	3	2	40gCa	(n,2n)	39gCa	16	20040.303
5	3	FPP		(n,ds)	FPP	28,22,103,105,107	
6	3	4		(n,g)	41gCa	102	
7	4	3	41gCa	(n,2n)	40gCa	16	20041.303
8	4	FPP		(n,ds)	FPP	28,22,103,105,107	
9	4	5		(n,g)	42gCa	102	
10	5	4	42gCa	(n,2n)	41gCa	16	20042.303
11	5	FPP		(n,ds)	FPP	28,22,103,107	
12	5	6		(n,g)	43gCa	102	
13	6	5	43gCa	(n,2n)	42gCa	16	20043.303
14	6	FPP		(n,ds)	FPP	22,103,104,107	
15	6	7		(n,g)	44gCa	102	
16	7	6	44gCa	(n,2n)	43gCa	16	20044.303
17	7	FPP		(n,ds)	FPP	103,104,107	
18	7	8		(n,g)	45gCa	102	
19	8	7	45gCa	(n,2n)	44gCa	16	20045.303
20	8	FPP		(n,ds)	FPP	103,104,107	
21	8	9		(n,g)	46gCa	102	
22	9	8	46gCa	(n,2n)	45gCa	16	20046.303
23	9	FPP		(n,ds)	FPP	103,107	
24	9	10		(n,g)	47gCa	102	
25	10	9	47gCa	(n,2n)	46gCa	16	20047.303
26	10	FPP		(n,ds)	FPP	103	
27	10	11		(n,g)	48gCa	102	
28	11	10	48gCa	(n,2n)	47gCa	16	20048.303
29	11	FPP		(n,ds)	FPP	103	
30	11	12		(n,g)	49gCa	102	
31	12	11	49gCa	(n,2n)	48gCa	16	20049.303
32	12	13		(n,g)	50gCa	102	
	13		50gCa				0.00

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	39 (0.861 s)	crsdata	ACTL - 1978		
40 (96.941%)		crsdata	ACTL - 1978		
	41 (1.03 10 <sup>5</sup> y)	crsdata	ACTL - 1978		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
42 (0.647%)		crsdata	ACTL - 1978		
43 (0.135%)		crsdata	ACTL - 1978		
44 (2.086%)		crsdata	ACTL - 1978		
	45 (162.7 d)	crsdata	ACTL - 1978		
46 (0.004%)		crsdata	ACTL - 1978		
	47 (4.536 d)	crsdata	ACTL - 1978		
48 (0.187%)		crsdata	ACTL - 1978		
	49 (8.72 m)	crsdata	ACTL - 1978		

## Eu – Europium (Z = 63)

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Production/Depletion for Europium Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT	Reactions	ZAID on Dosimetry Files
	1		149gEu					0.00
	2		150mEu					0.00
	3		150gEu					0.00
1	4	3	151gEu	(n,2n)	150gEu	16		63151.303
2	4	2		(n,2n)	150mEu	1016	See Note	
3	4	1		(n,3n)	149gEu	17		
4	4	FPP		(n,ds)	FPP	28, 22, 103, 104, 105, 106, 107		
5	4	5		(n,g)	152mEu	102		
6	4	6		(n,g)	152gEu	1102		
	5		152mEu					0.00
	6		152gEu					0.00
7	7	6	153gEu	(n,2n)	152gEu	16		63153.303
8	7	5		(n,2n)	152mEu	1016		
9	7	4		(n,3n)	151gEu	17		
10	7	FPP		(n,ds)	FPP	28, 22, 103, 104, 105, 106, 107		
11	7	8		(n,g)	154gEu	102		
	8		154gEu					0.00

Note: The numerical values for this cross section are identical to those for MT=16 immediately above.

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	146 (4.57 d)	-			
	147 (24.4 d)	-			
	148 (54.5 d)	-			
	149 (93.1 d)	-			
	150 (38 y)	-			
	150m (12.8 h)	-			
151		crsdata	ACTL - 1978		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
(47.81%)					
	152 (13.54 y)	-			
153 (52.19%)		crsdata	ACTL - 1978		
	154 (8.50 y)	-			
	155 (4.75 y)	-			
	156 (15.2 d)	-			
	157 (15.18 h)	-			

Ir – Iridium ( $Z = 77$ )

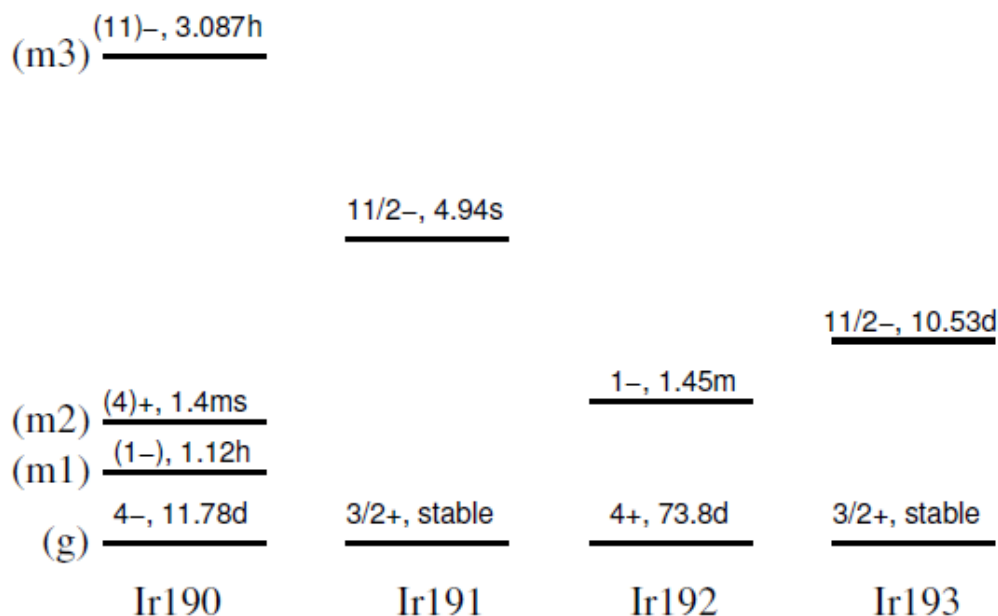


FIG. 6: The ground states and isomers of iridium isotopes.

Figure from (Chadwick, Frankle et al. 2007).

Original Y, Ir, and Tm evaluations were performed 1979-1981 by Ed Arthur in T-2 at LANL. From the original evaluations, what is in y21grp is the same for Ir as those original evaluations. Validation of some cross sections is discussed in (Chadwick, Frankle et al. 2007). The RC2004\_618 is discussed in (Trellue and White 2006) and (Trellue and White 2006).

The t16\_rc\_2004 data is discussed in (White 2005) and in (Talou, Kawano et al. 2006).

Reviews of the chains were done by (Little and Seamon 1986).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	188 (1.72 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	189 (13.2 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		
	190 (11.8 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		
191 (37.3%)		rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2006 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	192 (73.83 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		
193 (62.7%)		rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2006 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	193m (10.53 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2006 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	194 (171 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		



Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	194m (19.3 h)	mendf80	<i>Unavailable</i>		
	195 (3.9 h)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		

## Lu – Lutetium (Z = 71)

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	170 (2.01 d)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	171 (8.24 d)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	172 (6.70 d)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	172m3	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	172m2	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	172m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	173 (1.37 y)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	173m2	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	173m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	174 (3.3 y)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	174m3	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	174m2	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	174m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
175 (97.41%)		crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	175m2	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	175m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
176 (2.59%)		crsdata y21grp_n	ACTL - 1978 ACTL - 1978		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	176m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	177 (160.7 d)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	177m2	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	177m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	178 (28.5 m)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	178m1	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		
	179 (4.6 h)	crsdata y21grp_n	ACTL - 1978 ACTL - 1978		

## Nb – Niobium (Z = 41)

The Nb chain is discussed in (Seamon 1988).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	90 (14.6 h)	-			
	91 (62 d)	crsdata	ACTL - 1978		
	91m	crsdata	ACTL - 1978		
	92 (10.13 d)	crsdata	ACTL - 1978		
	92m	crsdata	ACTL - 1978		
93 (100%)		crsdata	ACTL - 1978		
	94 (6.253 m)	crsdata	ACTL - 1978		
	95 (34.99 d)	crsdata	ACTL - 1978		
	96 (23.4 h)	crsdata	ACTL - 1978		
	97 (1.25 h)	crsdata	ACTL - 1978		
	98 (51 m)	crsdata	ACTL - 1978		
	99 (2.6 m)	-			
	100 (3 s)	crsdata	ACTL - 1978		

Pb – Lead ( $Z = 82$ )

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	203 (2.164 d)	-			
204 (1.4%)		-			
	205 (1.57 y)	-			
206 (24.1%)		-			
207 (22.1%)		-			
208 (52.4%)		-			
	209 (3.25 h)	-			

## Rb – Rubidium (Z = 37)

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	82 (6.47 h)	-			
	83 (86.2 d)	-			
	84 (33.2 d)	-			
85 (72.17%)		-			
	86 (18.65 d)	-			
87 (27.83%)		-			

Re – Rhenium ( $Z = 75$ )

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	183 (70 d)	-			
	184 (35 d)	-			
185 (37.4 %)		-			
	186 (3.718 d)	-			
187 (62.6%)		-			
	188 (17.004 h)	-			
	189 (24 h)	-			

Rh – Rhodium ( $Z = 45$ )

Production/Depletion for Rhodium Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT Reactions	ZAID on Dosimetry Files
	1				102gRh		0.00
	2				103mRh		0.00
1	3	2	103gRh	(n,n')	103mRh	4	45103.303
2	3	1		(n,2n)	102gRh	16	

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above. Hoffman2009c is discussed in (Gray and Lee 2012) and (Hoffman, Kelley et al. 2006).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	96 (9.6 m)	Hoffman2009c	LLNL 2006		
	96m	Hoffman2009c	LLNL 2006		
	97 (46 m)	Hoffman2009c	LLNL 2006		
	97m	Hoffman2009c	LLNL 2006		
	98 (8.7 m)	Hoffman2009c	LLNL 2006		
	98m	Hoffman2009c	LLNL 2006		
	99 (16 d)	Hoffman2009c	LLNL 2006		
	99m	Hoffman2009c	LLNL 2006		
	100 (20.8 h)	Hoffman2009c	LLNL 2006		
	101 (3.3 y)	Hoffman2009c	LLNL 2006		
	101m (4.35 d)	Hoffman2009c	LLNL 2006		
	102 (3.74 y)	Hoffman2009c	LLNL 2006		



Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	102 m (207 d)	Hoffman2009c	LLNL 2006		
103 (100%)		Hoffman2009c	LLNL 2006		
	103m	Hoffman2009c	LLNL 2006		
	104 (4.36 m)	Hoffman2009c	LLNL 2006		
	104m	Hoffman2009c	LLNL 2006		
	105 (35.4 h)	Hoffman2009c	LLNL 2006		
	105m	Hoffman2009c	LLNL 2006		
	106 (2.18 h)	Hoffman2009c	LLNL 2006		
	160m	Hoffman2009c	LLNL 2006		

## Sc – Scandium (Z = 21)

Production/Depletion for Scandium Isotopes							ZAID on Dosimetry Files
Reaction	Target	Product	Target	Reaction	Product	MT Reactions	
	1			43gSc			0.00
1	2	1		44mSc	(n,2n)	43gSc	16
2	2	FPP		(n,ds)	FPP	103, 107	21044.313
3	2	4		(n,g)	45gSc	102	
4	3	1		44gSc	(n,2n)	43gSc	16
5	3	FPP		(n,ds)	FPP	103, 107	21044.303
6	3	4		(n,g)	45gSc	102	
7	4	3		45gSc	(n,2n)	44gSc	16
8	4	2		(n,2n)	44mSc	1016	21045.303
9	4	FPP		(n,ds)	FPP	103, 107	
10	4	5		(n,g)	46mSc	102	
11	4	6		(n,g)	46gSc	1102	
12	5	4		46mSc	(n,2n)	45gSc	16
13	5	FPP		(n,ds)	FPP	103, 107	21046.313
14	5	7		(n,g)	47gSc	102	
15	6	4		46gSc	(n,2n)	45gSc	16
16	6	FPP		(n,ds)	FPP	103, 107	21046.303
17	6	7		(n,g)	47gSc	102	
18	7	6		47gSc	(n,2n)	46gSc	16
19	7	4		(n,3n)	45gSc	17 See Note	21047.303
20	7	FPP		(n,ds)	FPP	103, 107	
21	7	8		(n,g)	48gSc	102	
22	8	7		48gSc	(n,2n)	47gSc	16
23	8	6		(n,3n)	46gSc	17 See Note	21048.303
24	8	FPP		(n,ds)	FPP	103, 107	
25	8	9		(n,g)	49gSc	102	
	9			49gSc			0.00

Note: Threshold for this reaction is above 17.0 MeV

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	44 (2.442 d)				
	44m				
45 (100%)					

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	46 (83.81 d)				
	46m				
	47 (3.349 d)				
	48 (43.7 h)				
	49 (57.3 m)				

## Ta – Tantalum (Z = 73)

Table VII  
Production/Depletion for Tantalum Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT Reactions	ZAID on Dosimetry Files
	1		177gTa				0.00
	2		178gTa				0.00
1	3	2	179gTa	(n,2n)	178gTa	16	73179.303
2	3	1		(n,3n)	177gTa	17	
3	3	FPP		(n,ds)	FPP	103	
4	3	4		(n,g)	180mTa	102	
5	3	5		(n,g)	180gTa	1102	
6	4	3	180mTa	(n,2n)	179gTa	16	73180.313
7	4	2		(n,3n)	178gTa	17	
8	4	FPP		(n,ds)	FPP	103	
9	4	6		(n,g)	181gTa	102	
10	5	3	180gTa	(n,2n)	179gTa	16	73180.303
11	5	2		(n,3n)	178gTa	17	
12	5	FPP		(n,ds)	FPP	28, 103, 104, 107	
13	5	6		(n,g)	181gTa	102	
14	6	5	181gTa	(n,2n)	180gTa	16	73181.303
15	6	4		(n,2n)	180mTa	1016	
16	6	3		(n,3n)	179gTa	17	
17	6	FPP		(n,ds)	FPP	22, 103	
18	6	7		(n,g)	182mTa	102	
19	6	8		(n,g)	182gTa	1102	
20	7	6	182mTa	(n,2n)	181gTa	16	73182.313
21	7	4		(n,3n)	180mTa	17	
22	7	FPP		(n,ds)	FPP	103	
23	7	9		(n,g)	183gTa	102	
24	8	6	182gTa	(n,2n)	181gTa	16	73182.303
25	8	4		(n,3n)	180mTa	17	
26	8	FPP		(n,ds)	FPP	103	
27	8	9		(n,g)	183gTa	102	
28	9	8	183gTa	(n,2n)	182gTa	16	73183.303
29	9	6		(n,3n)	181gTa	17	
30	9	FPP		(n,ds)	FPP	103	
31	9	10		(n,g)	184gTa	102	
32	10	9	184gTa	(n,2n)	183gTa	16	73184.303
33	10	8		(n,3n)	182gTa	17	
34	10	11		(n,g)	185gTa	102	
	11		185gTa				0.00
35	12	11	186gTa	(n,2n)	185gTa	16	73186.303
36	12	10		(n,3n)	184gTa	17	
37	12	13		(n,g)	187gTa	102	
	13		187gTa				0.00

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	179 (1.82 y)	crsdata	ACTL 1978		
180 (0.01%)		crsdata	ACTL 1978		
	180m	crsdata	ACTL 1978		
181 (99.99%)		crsdata	ACTL 1978		
	182 (114.43 d)	crsdata	ACTL 1978		
	182m	crsdata	ACTL 1978		
	183 (5.1 d)	crsdata	ACTL 1978		
	184 (8.7 h)	crsdata	ACTL 1978		
	185	-			
	186	crsdata	ACTL 1978		

## Tb – Terbium ( Z = 65)

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
159 (100%)		-			
	160 (72.3 d)	-			
	161 (6.91 d)	-			
	162 (7.6 m)	-			

## Tl – Thallium (Z = 81)

Production/Depletion for Thallium Isotopes							ZAID on Dosimetry Files
Reaction	Target	Product	Target	Reaction	Product	MT Reactions	
	1				<sup>200</sup> gTl		0.00
	2				<sup>201</sup> gTl		0.00
1	3	2		(n,2n)	<sup>201</sup> gTl	16	81202.303
2	3	1		(n,3n)	<sup>200</sup> gTl	17	
3	3	FPP		(n,ds)	FPP	28, 103	
4	3	4		(n,g)	<sup>203</sup> gTl	102	
5	4	3		(n,2n)	<sup>203</sup> gTl	16	81203.303
6	4	2		(n,3n)	<sup>201</sup> gTl	17	
7	4	FPP		(n,ds)	FPP	28, 103	
8	4	5		(n,g)	<sup>204</sup> gTl	102	
9	5	4		(n,2n)	<sup>203</sup> gTl	16	81204.303
10	5	3		(n,3n)	<sup>202</sup> gTl	17	
11	5	FPP		(n,ds)	FPP	28, 103	
12	5	6		(n,g)	<sup>205</sup> gTl	102	
13	6	5		(n,2n)	<sup>204</sup> gTl	16	81205.303
14	6	4		(n,3n)	<sup>203</sup> gTl	17	
15	6	FPP		(n,ds)	FPP	28, 103	
16	6	7		(n,g)	<sup>206</sup> gTl	102	
	7				<sup>206</sup> gTl		0.00

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	<sup>200</sup> (1.087 d)	-			
	<sup>201</sup> (3.043 d)	-			
	<sup>202</sup> (12.23 d)	crsdata	ACTL 1978		
<sup>203</sup> (29.52%)		crsdata	ACTL 1978		
	<sup>204</sup> (3.78 y)	crsdata	ACTL 1978		
<sup>205</sup> (70.48%)		crsdata	ACTL 1978		

Tm – Thulium ( $Z = 69$ )

Original Y, Ir, and Tm evaluations were performed 1979-1981 by Ed Arthur in T-2 at LANL.

The t16\_rc\_2004 data is discussed in (White 2005). Tm libraries may have come from C-INC before 1973 and Ed Arthur updated the (n,g) for 169 and 170 later. Validation of some cross sections is discussed in (Chadwick, Frankle et al. 2007). The RC2004\_618 is discussed in (Trellue and White 2006) and (Trellue and White 2006).

Reviews of the chains were done by (Little and Seamon 1986).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	166 (7.70 h)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	167 (9.24 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	168 (93.1 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
169 (100%)		rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	170 (128.6 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		



Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	171 (1.92 y)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	172 (2.65 d)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		
	173 (8.2 h)	rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n	LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980		

## V – Vanadium (Z = 23)

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	47 (32.6 m)	-			
	48 (15.98 d)	-			
	49 (331 d)	-			
50 (0.25%)		-			
51 (99.75%)		-			
	52 (3.76 m)	-			

## W – Tungsten (Z = 74)

Table VIII  
Production/Depletion for Tungsten Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT Reactions	ZAID on Dosimetry Files
	1		177gW				0.00
	2		178gW				0.00
1	3	2	179gW	(n,2n)	178gW	16	74179.303
2	3	1		(n,3n)	177gW	17	
3	3	4		(n,g)	180gW	102	
4	4	3	180gW	(n,2n)	179gW	16	74180.303
5	4	2		(n,3n)	178gW	17	
6	4	FPP		(n,ds)	FPP	28, 103, 104, 107	
7	4	5		(n,g)	181gW	102	
8	5	4	181gW	(n,2n)	180gW	16	74181.303
9	5	3		(n,3n)	179gW	17	
10	5	6		(n,g)	182gW	102	
11	6	5	182gW	(n,2n)	181gW	16	74182.303
12	6	4		(n,3n)	180gW	17	
13	6	FPP		(n,ds)	FPP	22, 103, 107	
14	6	7		(n,g)	183gW	102	
15	7	6	183gW	(n,2n)	182gW	16	74183.303
16	7	5		(n,3n)	181gW	17	
17	7	FPP		(n,ds)	FPP	28, 22, 103, 104, 107	
18	7	8		(n,g)	184gW	102	
19	8	7	184gW	(n,2n)	183gW	16	74184.303
20	8	6		(n,3n)	182gW	17	
21	8	FPP		(n,ds)	FPP	28, 103, 104, 107	
22	8	9		(n,g)	185gW	102	
23	9	8	185gW	(n,2n)	184gW	16	74185.303
24	9	7		(n,3n)	183gW	17	
25	9	10		(n,g)	186gW	102	
26	10	9	186gW	(n,2n)	185gW	16	74186.303
27	10	8		(n,3n)	184gW	17	
28	10	FPP		(n,ds)	FPP	22, 103, 107	
29	10	11		(n,g)	187gW	102	
30	11	10	187gW	(n,2n)	186gW	16	74187.303
31	11	9		(n,3n)	185gW	17	
32	11	8		(n,4n)	184gW	37	
33	11	12		(n,g)	188gW	102	
34	12	11	188gW	(n,2n)	187gW	16	74188.303
35	12	10		(n,3n)	186gW	17	
36	12	13		(n,g)	189gW	102	
	13		189gW				0.00

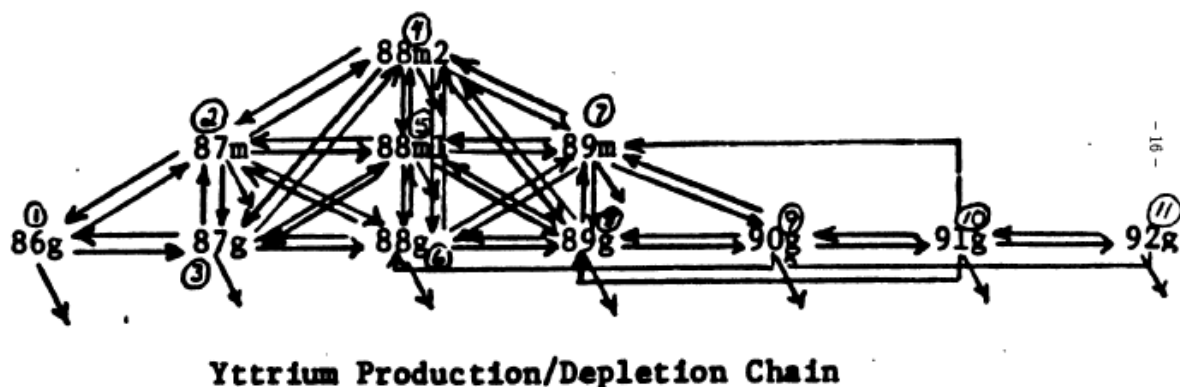
The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above.

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	179	crsdata	ACTL 1978		

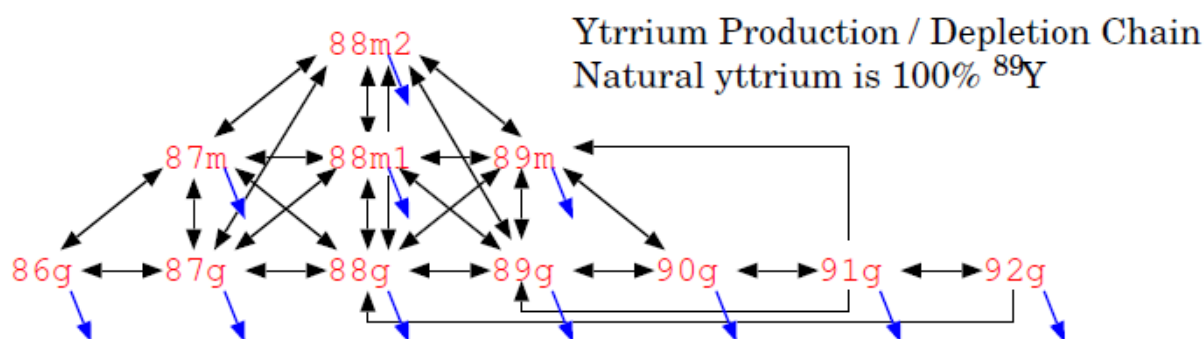
Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	(37.8 m)				
180 (0.12%)		crsdata	ACTL 1978		
	181 (121.2 d)	crsdata	ACTL 1978		
182 (26.50%)		crsdata	ACTL 1978		
183 (14.31%)		crsdata	ACTL 1978		
184 (30.64%)		crsdata	ACTL 1978		
	185 (74.3 d)	crsdata	ACTL 1978		
186 (28.43%)		crsdata	ACTL 1978		
	187 (23.9 h)	crsdata	ACTL 1978		
	188 (69.75 d)	crsdata	ACTL 1978		
	189 (19.7 m)	-			

Y – Yttrium ( $Z = 39$ )

The Y production/depletion chain is shown below taken from (Seamon 1989).



This nicer version below is from (Chadwick, Frankle et al. 2007).



Original Y, Ir, and Tm evaluations were performed 1979-1981 by Ed Arthur in T-2 at LANL.

The t16\_rc\_2004 data is discussed in (White 2005), Hoffman2009 in (Gray and Lee 2012) and (Hoffman, Kelley et al. 2006), and the crsllnl is discussed in (Seamon 1989). Validation of some cross sections is discussed in (Chadwick, Frankle et al. 2007). Impact of new Y cross sections on  $^{88}\text{Y}(n,2n)^{87}\text{Y}$  is discussed in (Chadwick, Kawano et al. 2004). The RC2004\_618 is discussed in (Trellue and White 2006) and (Trellue and White 2006).

Reviews of the chains were done by (Little and Seamon 1986) and (Seamon 1986).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	84 (40 m)	Hoffman2009c	LLNL 2006		
	84m	Hoffman2009c	LLNL 2006		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	85 (4.9 h)	Hoffman2009c	LLNL 2006		
	85m	Hoffman2009c	LLNL 2006		
	86 (14.74 h)	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	86m	Hoffman2009c	LLNL 2006		
	87 (3.35 d)	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	87m	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	88 (106.63 d)	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	88m2	Hoffman2009c rc2006_618 rc2004_618	LLNL 2006 LANL 1980 LANL 1980		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
		t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	88m1	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
89 (100%)		Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 2004 LANL 2004 LANL 2004 LANL 1980 LANL 1980 LANL 1980 LLNL 1980		
	89m	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	90 2.669 d	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	90m	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980		

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
		y21grp_n crsllnl	LANL 1980 LLNL <1989		
	91 (58.5 d)	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	91m	Hoffman2009c	LLNL 2006		
	92 (3.54 h)	Hoffman2009c rc2006_618 rc2004_618 t16_rc_2004 crsdata y21grp y21grp_n crsllnl	LLNL 2006 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LANL 1980 LLNL <1989		
	93 (10.2 h)	Hoffman2009c	LLNL 2006		
	93m	Hoffman2009c	LLNL 2006		



## Zr – Zirconium (Z = 40)

Production/Depletion for Zirconium Isotopes

Reaction	Target	Product	Target	Reaction	Product	MT Reactions	ZAID on Dosimetry Files
1	1		88gZr				0.00
2	2	1 FPP	89gZr	(n,2n)	88gZr	16	
3	2	3		(n,ds)	FPP	103, 107	40089.303
				(n,g)	90gZr	102	
4	3	2	90gZr	(n,2n)	89gZr	16	
5	3	3 FPP		(n,ds)	FPP	28, 103, 104, 107	40090.303
6	3	4		(n,g)	91gZr	102	
7	4	3	91gZr	(n,2n)	90gZr	16	
8	4	2		(n,3n)	89gZr	17	40091.303
9	4	4 FPP		(n,ds)	FPP	28, 103, 104, 107	
10	4	5		(n,g)	92gZr	102	
11	5	4	92gZr	(n,2n)	91gZr	16	
12	5	3		(n,3n)	90gZr	17	40092.303
13	5	5 FPP		(n,ds)	FPP	28, 103, 104, 107	
14	5	6		(n,g)	93gZr	102	
15	6	5	93gZr	(n,2n)	92gZr	16	
16	6	4		(n,3n)	91gZr	17	40093.303
17	6	6 FPP		(n,ds)	FPP	103, 107	
18	6	7		(n,g)	94gZr	102	
19	7	6	94gZr	(n,2n)	93gZr	16	
20	7	5		(n,3n)	92gZr	17	40094.303
21	7	7 FPP		(n,ds)	FPP	22, 103, 107	
22	7	8		(n,g)	95gZr	102	
23	8	7	95gZr	(n,2n)	94gZr	16	
24	8	6		(n,3n)	93gZr	17	40095.303
25	8	8 FPP		(n,ds)	FPP	103, 107	
26	8	9		(n,g)	96gZr	102	
27	9	8	96gZr	(n,2n)	95gZr	16	
28	10	9	97gZr	(n,2n)	96gZr	16	40096.303
29	10	8		(n,3n)	95gZr	17	40097.303
30	10	10 FPP		(n,ds)	FPP	107	
31	10	11		(n,g)	98gZr	102	
	11		98gZr				0.00

Note: Threshold for this reaction is above 17.0 MeV

The ACTL data is discussed in (Little and Seamon 1987) with the production/depletion reactions shown above. Hoffman2009 is discussed in (Gray and Lee 2012) and (Hoffman, Kelley et al. 2006).

Stable Isotopes (Percent Abundance)	Radioactive Isotopes of Interest (Half-Life)	Cross Section Libraries	Evaluated Data	Theoretical Needs	Experimental Needs
	86 (14.74 h)	Hoffman2009c	LLNL 2006		
	87 (1.71 h)	Hoffman2009c	LLNL 2006		
	87m	Hoffman2009c	LLNL 2006		
	88 (83.4 d)	Hoffman2009c	LLNL 2006		
	89 (3.27 d)	Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	89m	Hoffman2009c	LLNL 2006		
90 (51.45%)		Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	90m3	Hoffman2009c	LLNL 2006		
	90m2	Hoffman2009c	LLNL 2006		
	90m1	Hoffman2009c	LLNL 2006		
91 (11.22%)		Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	91m	Hoffman2009c	LLNL 2006		
92 (17.15%)		Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	93 (1.5 10 <sup>6</sup> y)	Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
94 (17.38%)		Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	95 (64.02 d)	Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
96 (2.80%)		Hoffman2009c crsdata	LLNL 2006 ACTL 1976		
	97 (16.75 h)	crsdata	ACTL 1976		

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